Estimation of Fake Lepton Background in the Two Same-sign Lepton ttH Final States with the ATLAS Experiment

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PHD Status

Detector Performance

- Finalize 2015 reconstruction efficiency measurements using local CPPM framework.
- Present T&P group in e/gamma workshop 2015.
- Present LHCC egamma poster on March 2016.
- Contributed in the CONF note.
- Help to transfer CPPM code to the official framework.
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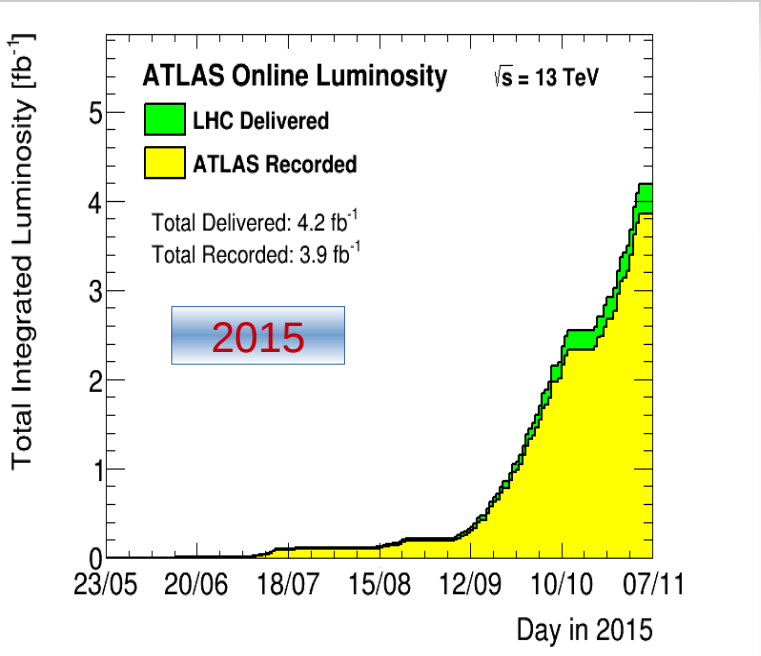
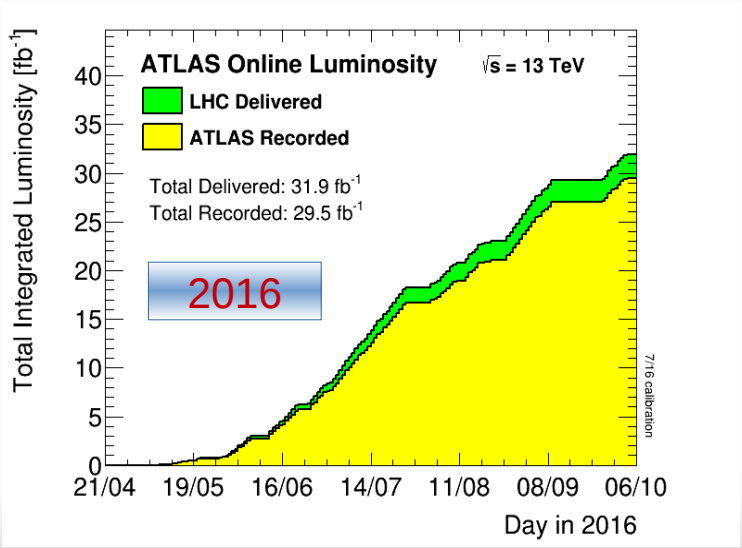
Kevin's talk!

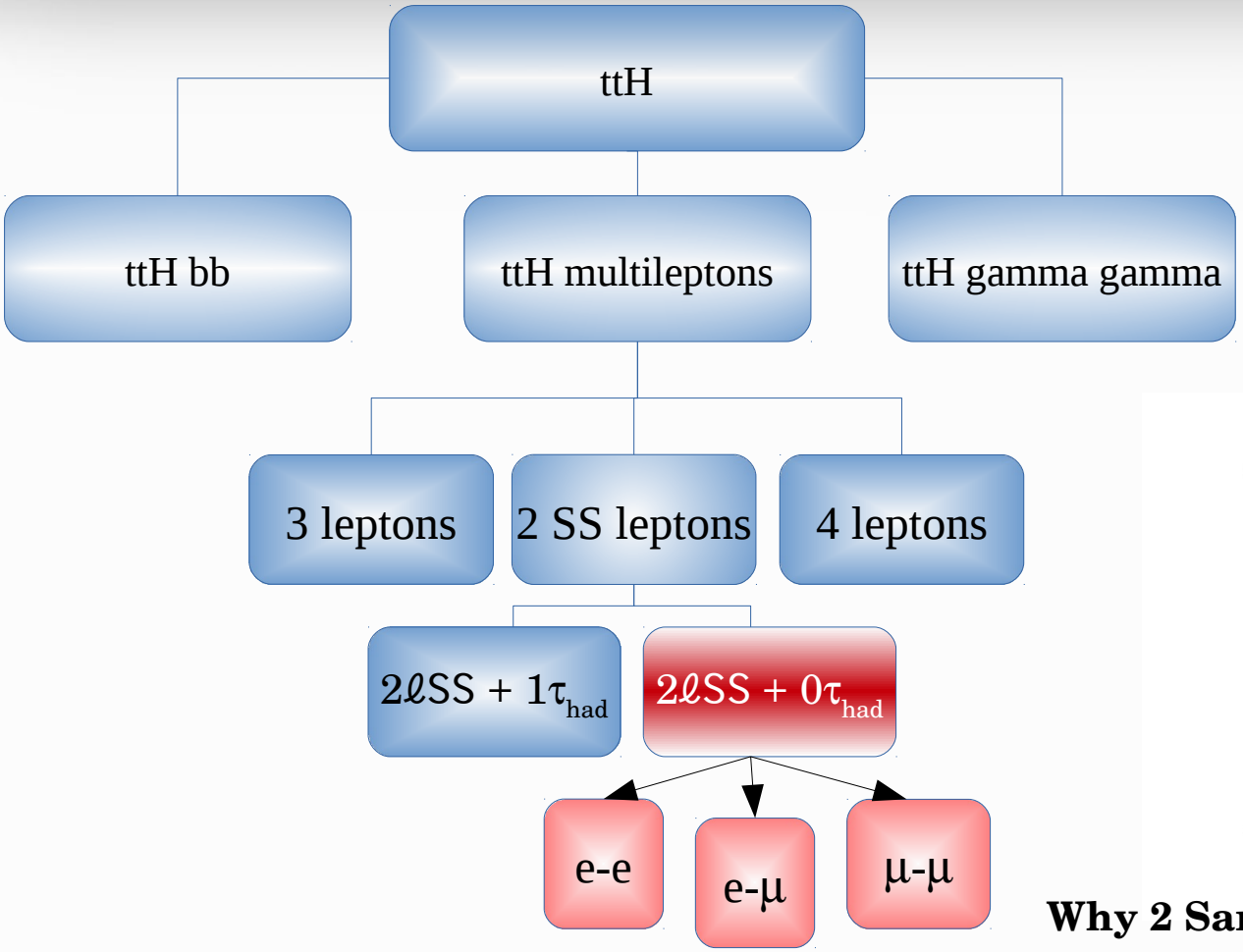




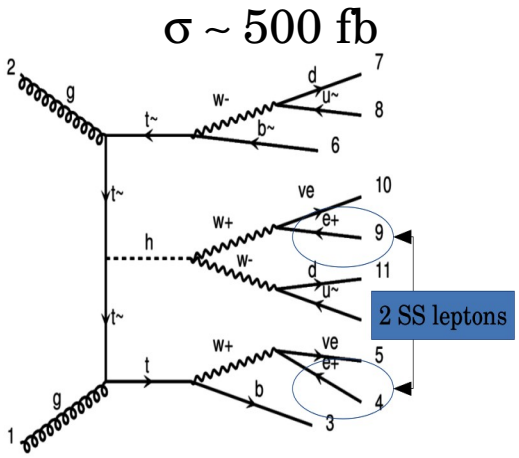
ttHML analysis:

- Introduce Matrix method as a cross check in the internal note.
- Contributed in the Conf note released on August 2016.
- Presented the ttHML group in HTop workshop at CERN on 3rd of October 2016.

Introduction



Low signal efficiency!



Why 2 Same Sign-charge (SS) leptons?

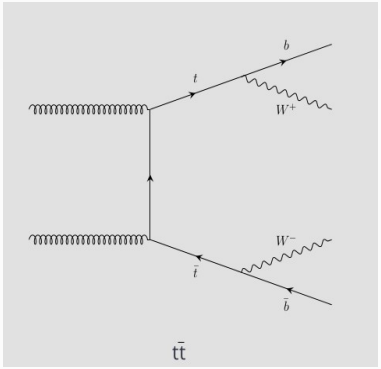
Almost SM background free

Challenge: Measure and reduce Fake lepton background!

Background

Reducible

σ ~ 908 000 fb



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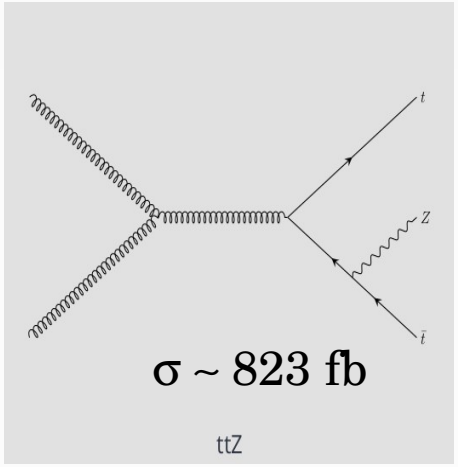
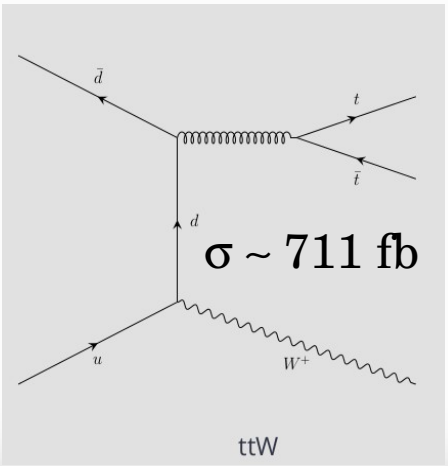
Irreducible

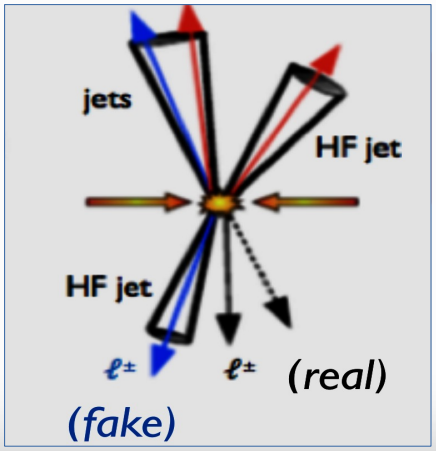


ttZ

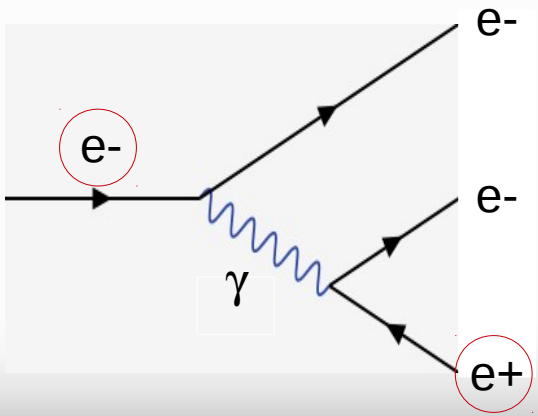


ttW

Fake Leptons



Charge Flip



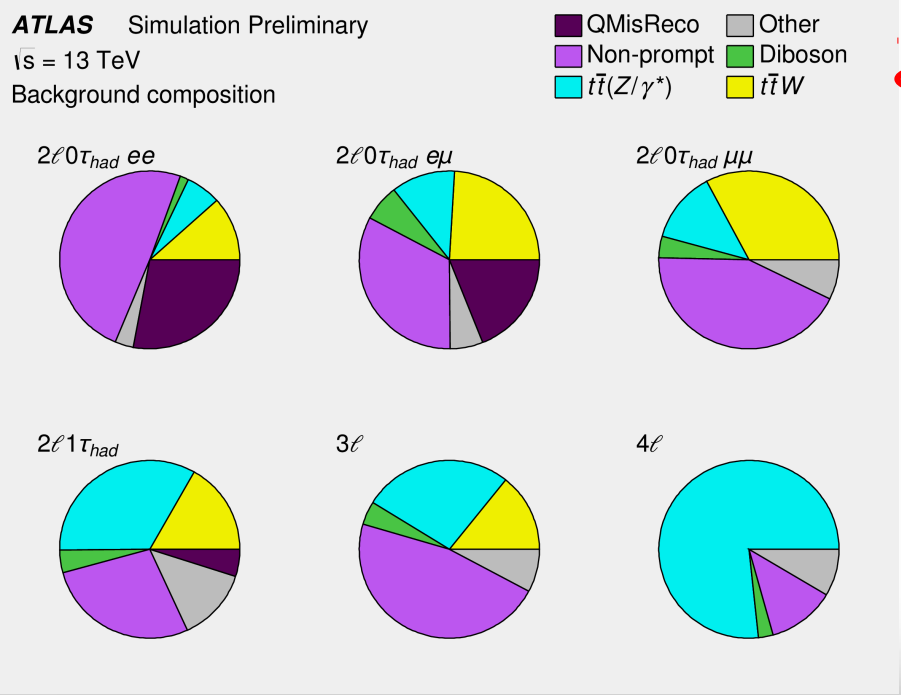
Fake Leptons

What are fake leptons?

- Miss reconstructed objects as leptons.
- non prompt leptons decaying from heavy hadrons.

Why fakes?

- Non negligible background in all channels.
- Contribute by 30-45% in 2ℓ and 3ℓ channels.
- Driving the error on the total background.

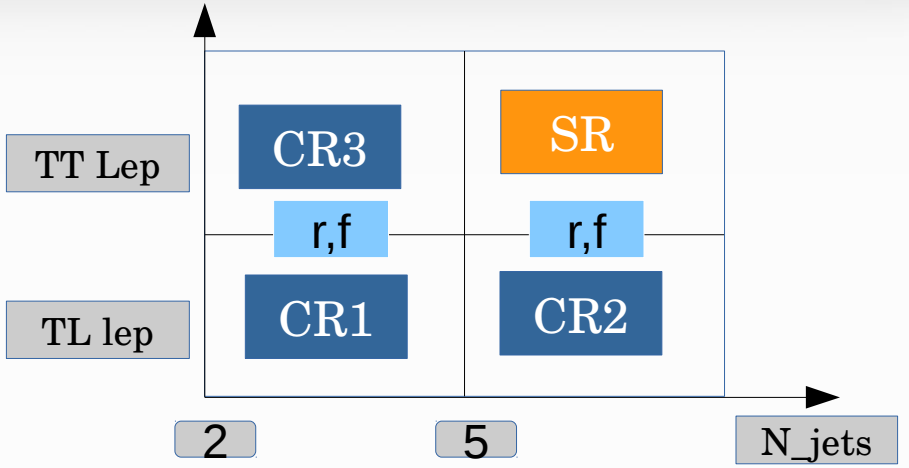


Uncertainty Source	$\Delta\mu$	
Non-prompt leptons and charge misreconstruction	+0.56	−0.64
Jet-vertex association, pileup modeling	+0.48	−0.36
$t\bar{t}W$ modeling	+0.29	−0.31
$t\bar{t}H$ modeling	+0.31	−0.15
Jet energy scale and resolution	+0.22	−0.18
$t\bar{t}Z$ modeling	+0.19	−0.19
Luminosity	+0.19	−0.15
Diboson modeling	+0.15	−0.14
Jet flavor tagging	+0.15	−0.12
Light lepton (e,μ) and τ_{had} ID, isolation, trigger	+0.12	−0.10
Other background modeling	+0.11	−0.11
Total systematic uncertainty	+1.1	−0.9

Matrix Method: Introduction

Principle:

- 3 control regions (CR) are defined according to jet multiplicity and Tight (T), Loose (L) lepton selection.
- T&P method to estimate the real efficiency *r* and fake rate *f*.
- Input: Yields passing/ failing tight selection (N^{TT},$N^{T!T}$,$N^{!TT}$,$N^{!T!T}$).
- Charge flip (CF) is subtracted in each region using CF rates (W_{TT}^{CF}).

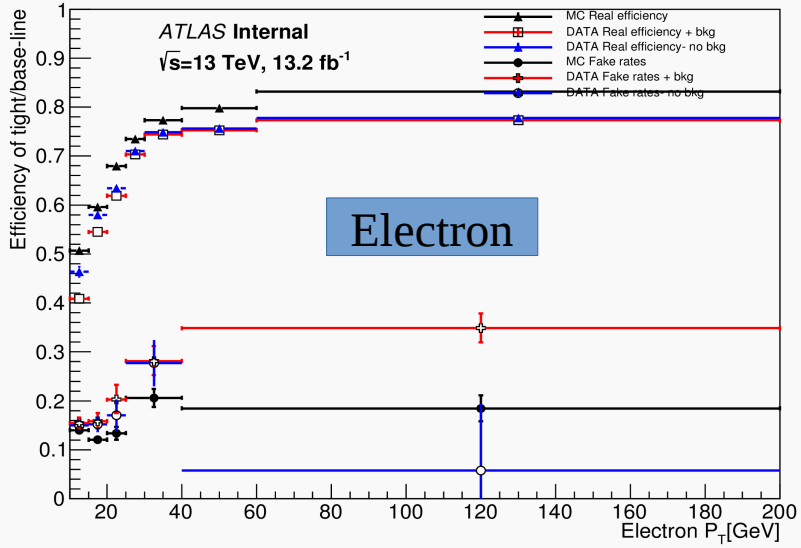


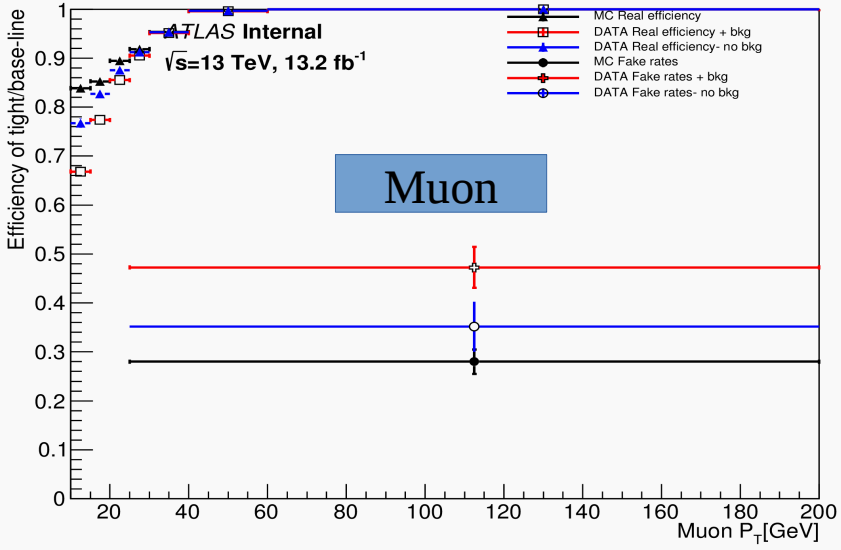
$$N_f^{TT} = N_{rf}^{TT} + N_{fr}^{TT} + N_{ff}^{TT} = r_1 f_2 N_{rf}^{LL} + r_2 f_1 N_{fr}^{LL} + f_1 f_2 N_{ff}^{LL} =$$
$$(MM^{TT}) \cdot N^{TT} + (MM^{T\bar{T}}) \cdot N^{T\bar{T}} + (MM^{\bar{T}T}) \cdot N^{\bar{T}T} + (MM^{\bar{T}\bar{T}}) \cdot N^{\bar{T}\bar{T}} =$$
$$[1 - \alpha(r_1 r_2 (1-f_1)(1-f_2))] \cdot N^{TT} + [\alpha r_1 r_2 f_2 (1-f_1)] \cdot N^{T\bar{T}} +$$
$$+ [\alpha r_1 r_2 f_1 (1-f_2)] \cdot N^{\bar{T}T} + [-\alpha r_1 r_2 f_1 f_2] \cdot N^{\bar{T}\bar{T}}$$

$$N^{TT} = N_{SS}^{TT} - W_{TT}^{CF} \times N_{OS}^{TT}$$

Electrons		
	Loose (baseline)	Tight
Minimum p_T	10 GeV	—
$\lvert\eta\rvert$	≤ 1.37	—
$\lvert d_0^{sig}\rvert$	5	—
$\lvert z_0 \sin\theta\rvert$	0.5 mm	—
Isolation	Loose	FixedCutTight
Electron ID	LooseLH	TightLH
Muons		
	Loose (baseline)	Tight
Minimum p_T	10 GeV	—
$\lvert\eta\rvert$	≤ 2.5	—
$\lvert d_0^{sig}\rvert$	3	—
$\lvert z_0 \sin\theta\rvert$	0.5 mm	—
Isolation	Loose	FixedCutTightTrackOnly
Quality	Loose	—

Matrix Method: Efficiency Measurements





$$r = \frac{N_{OS}^{Tight\ probes} - N_{Fake\ OS}^{MC\ Tight\ probes}}{N_{OS}^{Loose\ probes} - N_{Fake\ OS}^{MC\ Loose\ probes}}$$

$$f = \frac{N_{SS}^{Tight\ probes} - N_{real\ SS}^{MC\ Tight\ probes} - N_{CF}^{Tight\ probes}}{N_{SS}^{Loose\ probes} - N_{real\ SS}^{MC\ Loose\ probes} - N_{CF}^{Loose\ probes}}$$

- Select a real-enriched CR (Real CR) and fake-enriched CR (Fake CR).
- measure efficiency for probe leptons passing Tight selection in bins of p_T.
- Apply tag and probe T&P method:

  tag: the first Tight and trigger-matched lepton in event (starting from leading lepton)

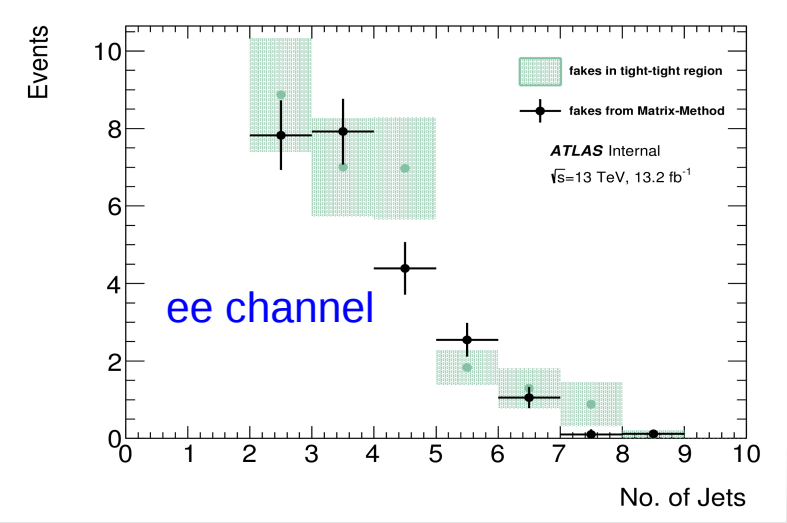
  probe: the other one (can be Tight or not) .

Matrix Method: Validity

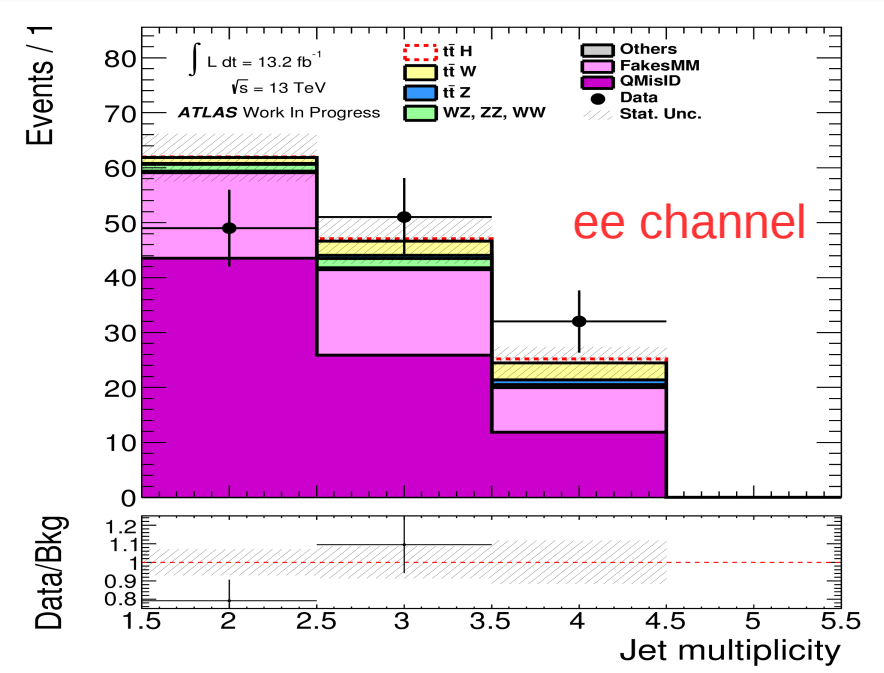
MC Closure Test

ttbar events with non-prompt lepton.

Flavor	Region	Non-closure	Sys
ee	5 jets	-29 ± 14	**29 %**
eμ	5jets	-27 ± 10	**27 %**
μμ	5 jets	-2 ± 18	**20 %**



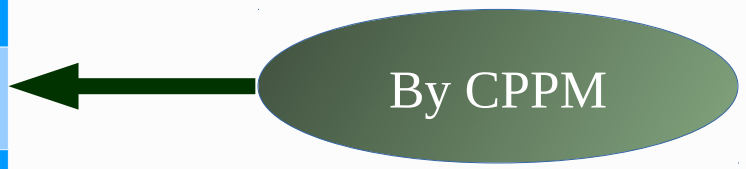
DATA Closure Test



Matrix Method: Fake Estimate

Cross Check with Fake Factor Method

Channel	μμ	eμ	ee
MM (DD CF)	7.0 ± 2.1	8.4 ± 2.6	8.5 ± 2.6
MM (MC CF)	7.3 ± 2.1	13.7 ± 3.3	9.0 ± 2.5
FF	8.7 ± 2.9	12.4 ± 3.5	12.1 ± 3.8



Uncertainty

- Source of statistical uncertainties: Size of low jet and high jet multiplicity regions.
- Source of systematics: (conservative by 50%)

Validity of the extrapolation: closure tests.

Normalisation of subtracted prompts.

Fake region composition: stability tests.

– Systematic uncertainty is dominating.

– More deep study of systematics is ongoing!

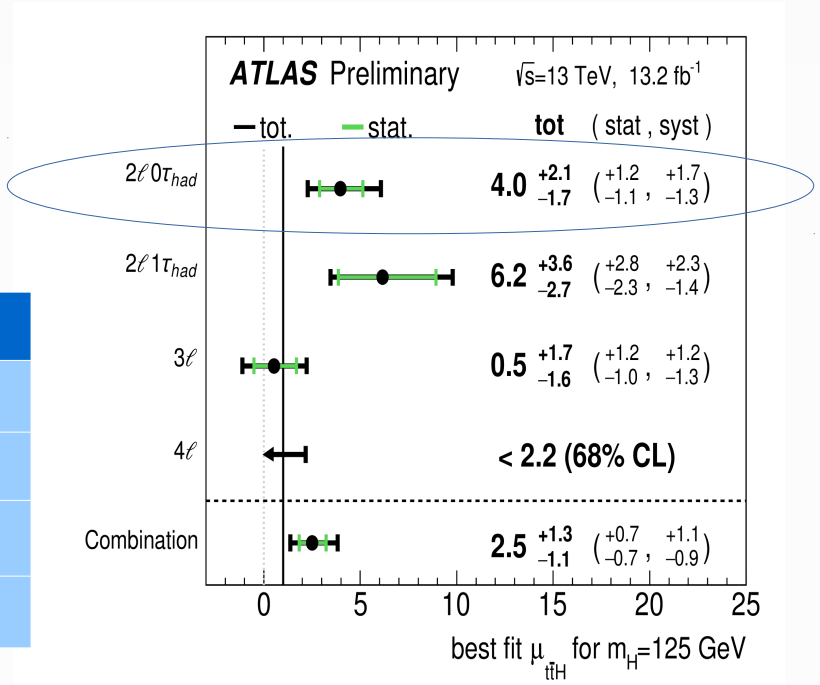
Channel	μμ	eμ	ee
Stat	2.1	2.6	2.6
Sys	3.0	5.7	2.8

Conclusion

Results are shown for the international conference on high energy physics ICHEP @ luminosity of 13.2 fb^{-1} using collected data in 2015-2016.

Fake lepton estimation plays a major role in multilepton analysis.

Channel	ee5j	em5j	mm5j
Fakes	12.0 ± **6.0**	12.0 ± **5.0**	8.7 ± **3.4**
QmisId	6.9 ± 1.3	7.1 ± 1.7	-
B_{red}/B_{tot}	75.6%	50.3%	43.5%
Total	27 ± **6.0**	42.8 ± **6.1**	22.9 ± **4.04**



Outlook

Currently updating my results with 35 fb^{-1} and work towards paper completion.

Consistency with the Standard Model expectation.

Outlook

- Systematics are dominated by fakes.
- Need to reduce fake contamination.
- If possible reduce systematics.
- Use matrix method as input of MVA?

process	el-el	el-mu	mu-mu	total
ttH	2.00	5.27	3.53	**10.80**
ttW	2.92	9.86	7.64	**20.41**
ttZ	1.69	4.41	2.67	**8.78**
VV	0.38	2.60	0.86	**3.84**
ttbar	7.93	16.09	4.37	**28.39**
Rare	0.86	2.45	1.62	**4.93**
Total bkg	**13.78**	**35.40**	**17.17**	**66.35**
Total	15.77	40.68	20.70	**77.15**
S/B	0.14	0.15	0.21	**0.16**
S/sqrt(B)	0.54	0.89	0.85	**1.33**

Cut based cut

MVA

el-el	el-mu	mu-mu	total
1.77	4.83	4.00	**10.60**
2.35	8.42	7.98	**18.76**
1.47	3.82	3.01	**8.30**
0.83	1.96	0.95	**3.74**
3.02	8.51	2.62	**14.14**
0.74	2.20	1.80	**4.74**
8.40	**24.91**	**16.36**	**49.67**
10.18	29.74	20.36	**60.28**
0.21	0.19	0.24	**0.21**
0.61	0.97	0.99	**1.50**

MVA cut + number of jets >= 5